Complete ECG Generator System

USER MANUAL

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1. Introduction

1.1. Purpose

The system offers complete solution for development and testing of analogue hardware of cardiac devices using various geometric waveforms and ECG analysis algorithms by generating real analogue signals using MIT and other compatible ECG databases. Complete ECG Generator (CEG) system creates custom annotation files that can be compared against the original database annotation files using bxb application.

In addition, the system generates simplified waveforms with various rhythm abnormalities for the preliminary testing of autotrigger algorithms.

1.2. System Organization

System includes two main components:
- Complete ECG Generator device (**Device**)
- Complete ECG Generator application (**Application**)

Complete ECG Generator Device

Complete ECG Generator device generates high accuracy (+/- 1% amplitude and timing tolerance) dual channel analogue signals converting digital data received from Complete ECG Generator application.

In addition to its signal generation function, the Device is able to receive from the cardiac device under the test digital signals such as QRS pulse, Trigger pulse and Special Event signal (for instance, inhibition of real time analysis due to excessive noise). The Complete ECG Generator Device sends these signals to the Application that stores them as a custom annotation file.

For the development purposes Device has higher voltage signal outputs with DAC reference 2.048V (0 - 4.096V output) that can be interfaced directly to the emulators, omitting front end amplifiers to avoid common mode interference.

Complete ECG Generator Device is powered by the USB bus that eliminates the need for the batteries or power adaptors and has a floating section that generates analogue signals converting received from the PC digital data using 12-bit DAC. Floating section has optically isolated data lines and is powered by isolated DC-DC converter.

Complete ECG Generator Application

Complete ECG Generator application is Windows based software that controls operation of Complete ECG Generator device.

Functions of Application include:

- testing of USB interface,
- settings for Application desktop options,
- selection of signal category (database signals, ECG amplifier testing signals, ANSI/AAMI EC130210:2002 recommended signals or Rhythm abnormalities signals),
- setting of generated signal parameters,

- batch option to sequentially reproduce all ECG database recordings from the selected folder,

- display of generated waveforms, QRS, Trigger and Special Event markers received from the device under the test,

- display of elapsed time and other relevant information during signal generation,

- generates annotation file for all ECG recordings where QRS, Trigger or Special Event markers have been generated. Each annotation file is saved under unique name,

- perform bxb analysis for two annotation files (reference and test).

Generated signals are divided into four categories:

- **ECG Database signals** include all **MIT-BIH** and some other compatible database recordings, generated for the entire duration of the recordings without any signal modification or padding,

- **ECG Amplifier testing signals** such as *square, sine, triangle, sawtooth* waves and *DC Offset* signal. Settings for frequency and amplitude of these signals offer wide variety of choices for amplifier and filters testing and calibration,

- **Test Waveforms (ANSI/AAMI EC130210:2002** recommended signals that used for testing of particular requirements and essential performance of cardiac equipment),

- **Rhythm abnormalities signals** that used for the preliminary testing of autotrigger algorithms

WARNING! Due to very sensitive timing requirements of Windows operating system it is recommended to use a "clean computer" which is not connected to the Internet and does not use residential software like antivirus. It is also recommended not to start any other application while Complete ECG Generator is in operation.

Starting the System

Upon connection to the USB bus the generator illuminates its yellow LED and green LED blinks several times indicating that the Device is ready to be initialised by the Complete ECG Generator Application. During normal operation green LED blinks every second.

2. Requirements to the System

PC Hardware minimal requirements
- CPU 2 GHz
- RAM 2 GB
- Graphics card resolution 1024x768
- USB port
- 200 MB HDD free space

PC Software minimal requirements
- Windows XP SP3 +
- FTDI driver. The Device uses USB port of the computer to communicate with software Application. Floating section of the Device is optically isolated from the computer in order to eliminate common mode noise. Since optical isolation of the USB signals is not a trivial task, RS232 protocol is used to transfer data to and from the floating section of the Device. FTDI chip converts RS232 data format into USB

data format. FTDI driver implements a virtual RS232 port on the computer that is in fact connected to the USB port. (See **FTDI Driver** reference in **Appendix A**)

- Adobe Acrobat Reader (See **Adobe Acrobat Reader** reference in **Appendix A**)

3. Features of the System

Low voltage output

Low voltage output includes three signals: CH1, CH2 and reference voltage. Voltage levels on the low voltage output correspond to format 212 of various ECG databases. Three press stud type connector headers are placed on the top side of the generator. This output is implemented for testing of electrocardiographic equipment including front end circuitry. ***Note:*** Shielded and short ECG leads should be used to connect device under test to the generator in order to minimise common mode noise that can be picked up by the leads.

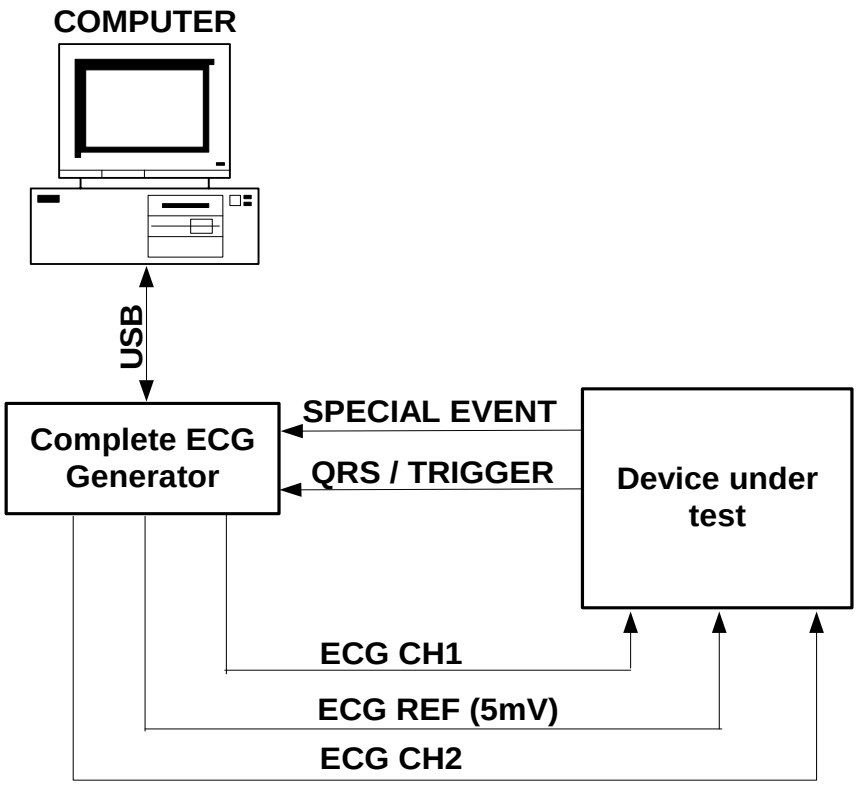


FIG. 3.1 Connection diagram of Complete ECG Generator Device under Test

High voltage output

High voltage output that available on 2.5mm stereo jack connector (see FIG 1.4) includes three signals: CH1, CH2 and ground. Voltage levels on the high voltage output correspond to 0 to 4.096V full scale with 2.048V reference. This output is implemented for testing of electrocardiographic equipment on the development stages using emulators.

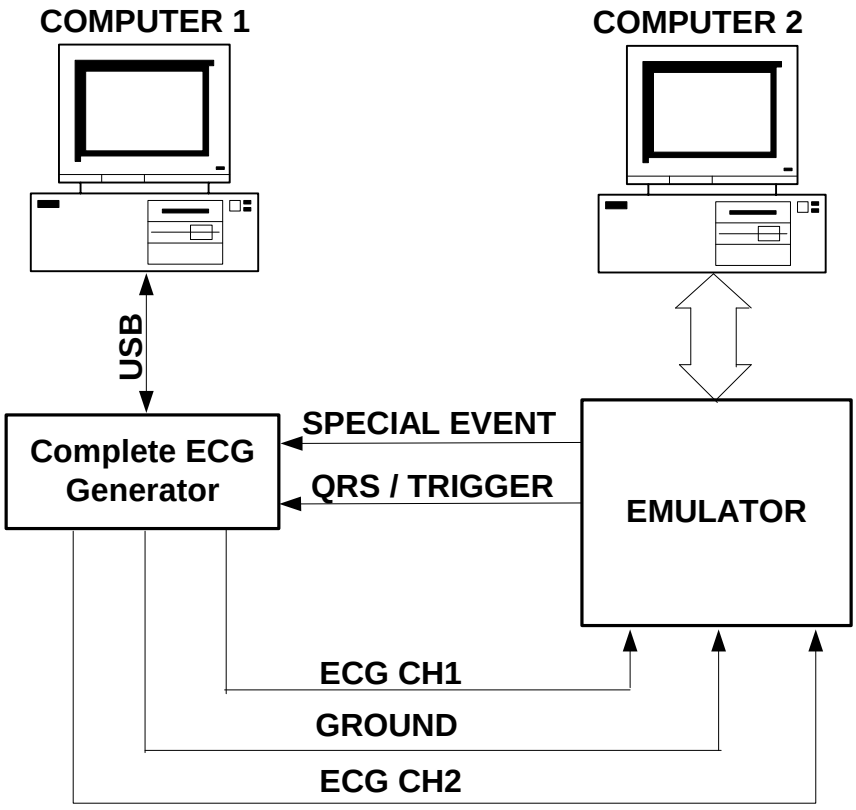


FIG. 3.2 Connection diagram of Complete ECG Generator Device
for development using emulator

Hook up inputs

The generator has two hook up inputs that allow for creating of custom annotation files for further comparison them against the original database annotation. The hook up inputs are available on 3.5mm stereo jack connector (see FIG 3.4)

NOTE: Annotation file is created ONLY when the entire recording was replayed.

QRS/Trigger input

QRS/Trigger input accepts logic level pulses that are generated by the device under test and correspond to the detected QRS waves or by rhythm analysis trigger. The device under the test generates 5mS pulse when QRS has been detected or 50mS pulse when QRS/Trigger occurred See FIG 3.3.

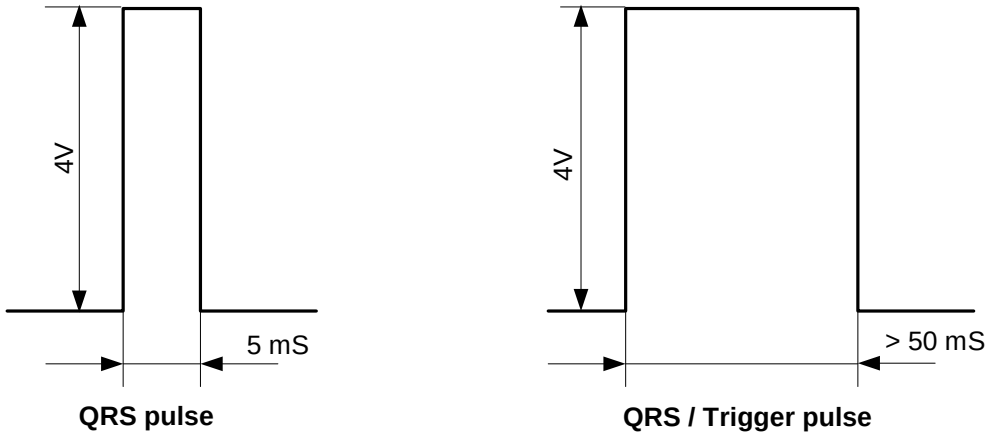


FIG. 3.3 QRS and Trigger signals

Note that decision to declare a trigger coincides with detection of the QRS when rhythm analysis is performed. Therefore, trigger pulse is also treated as a QRS. When the Generator receives from the device under the test QRS/Trigger pulses, it transmits a corresponding number of the digital sample to the PC and that number is stored in the custom annotation file. The Generator also displays QRS/Trigger markers. The generator distinguishes between QRS and trigger pulses and sends to the PC two different codes.

Special event input

Special event input accepts logic level signal that corresponds to the selected by the developer event that is generated by the embedded firmware. Special event has its beginning when the signal is set high and the end when the signal is set low.

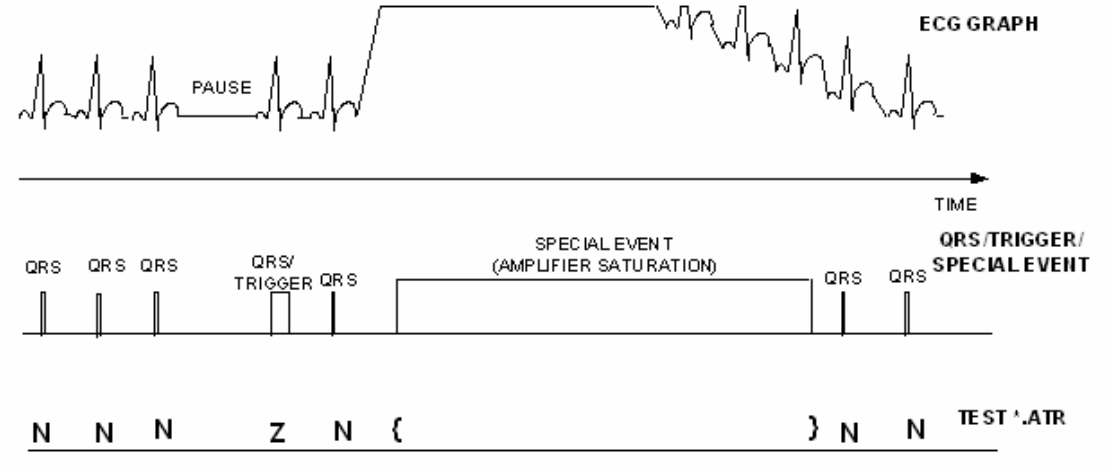


FIG. 3.4 QRS/Trigger and special event signals and ECG data relationship when embedded firmware inhibited QRS detection due to amplifier saturation

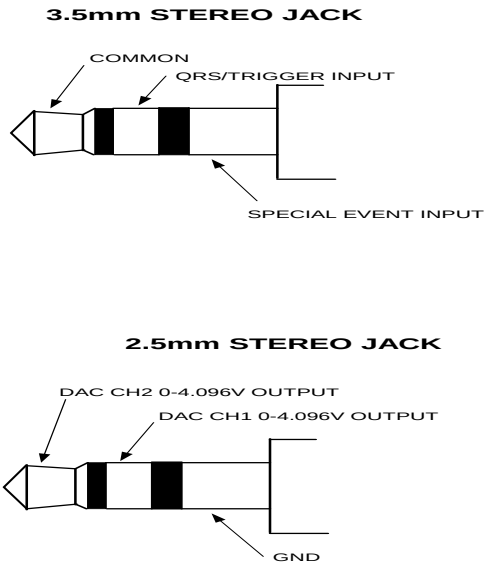
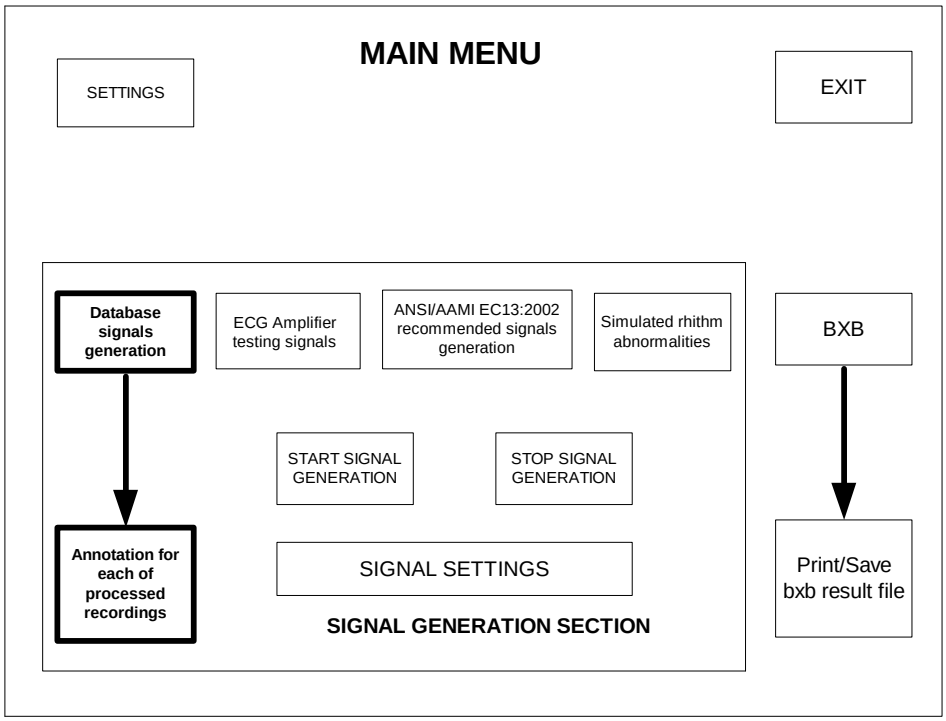


FIG. 3.5 Pin assignment of input and output connectors

NOTE: In case of excessive common mode noise use laptop computer with battery power supply (see also Appendix E)

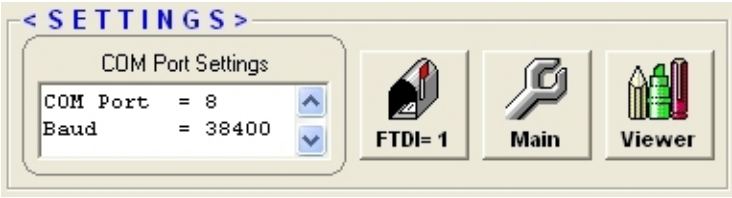
4. Software structure of the CEG Application

Block diagram of software structure is shown below



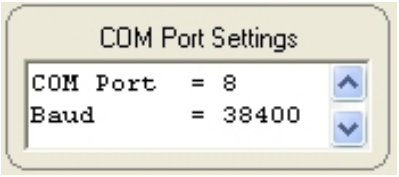
4.1. Settings section

Settings section includes all settings that control operation of the Complete ECG Generator.



4.1.1 COM Port Settings

Shows PC COM Port selected for connection to the Device.



4.1.2 FTDI status

FTDI button shows number of connected FTDI devices to PC and when depressed, updates status.

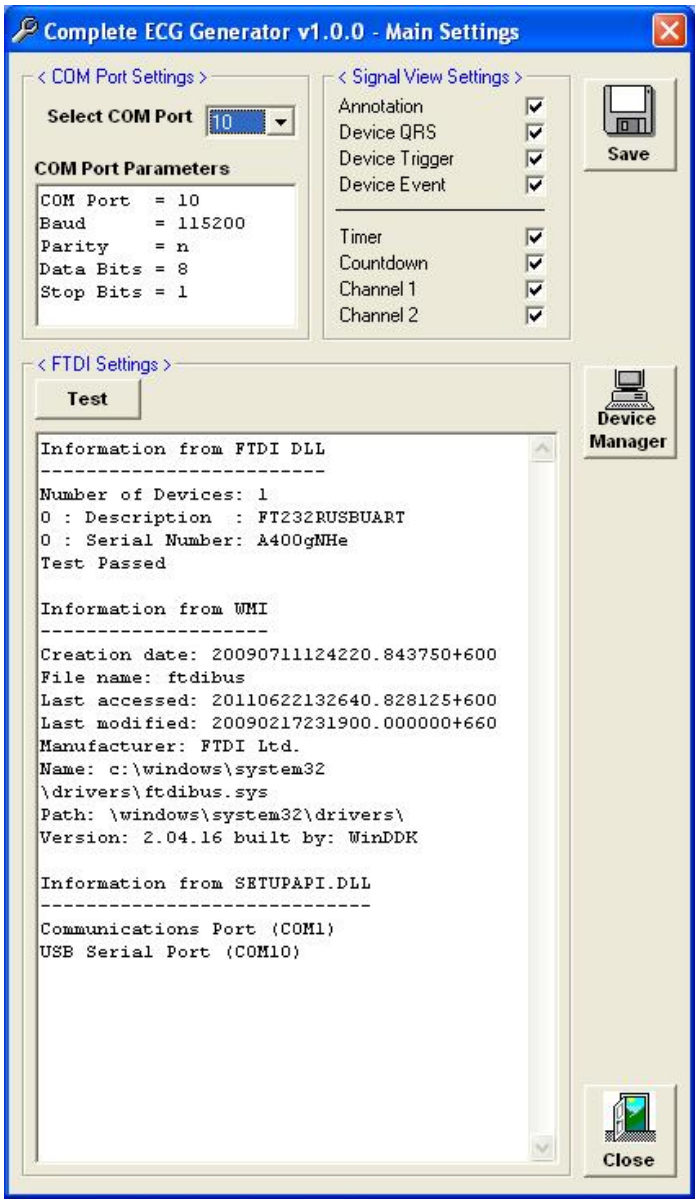
no FTDI device is connected to the PC

FTDI device(s) connected to the PC. Red flag on the icon indicates that FTDI device is detected.

4.1.3 Main settings section

To open Main Settings click the button below

Main Settings interface includes 3 sections.



4.1.3.1 Selection of COM Port

Using button “Test” (FTDI Settings) check available COM ports on your computer. Select COM Port number (Select COM Port) that corresponds to the USB Serial Port on your PC.

4.1.3.2 FTDI Settings

This section allows for testing FTDI devices, connected to the PC.
NOTE: It is recommended that only one FTDI device is connected to the PC during operation of the Complete ECG Generator system.

4.1.3.3 Signal View Settings

This section enables/disables display of various variables during signal generation.

4.1.3.4 Save settings

To save settings click **Save** button.

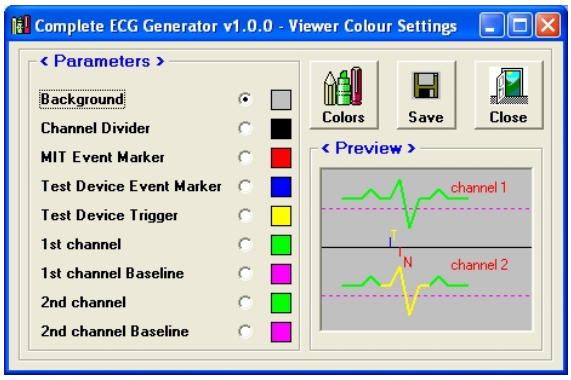
4.1.3.5 Open Device Manager

To open Windows' Device Manager (where available COM ports can be seen or renamed if required) click **Device Manager** button.

4.1.4 Viewer Settings

To open Viewer Settings click the button below.

Viewer Settings interface includes 2 sections.



Parameters section

- shows signal graph window color settings
- allows to select color setting for each listed item

Preview section

- shows signal sample with color settings from *Parameters* section

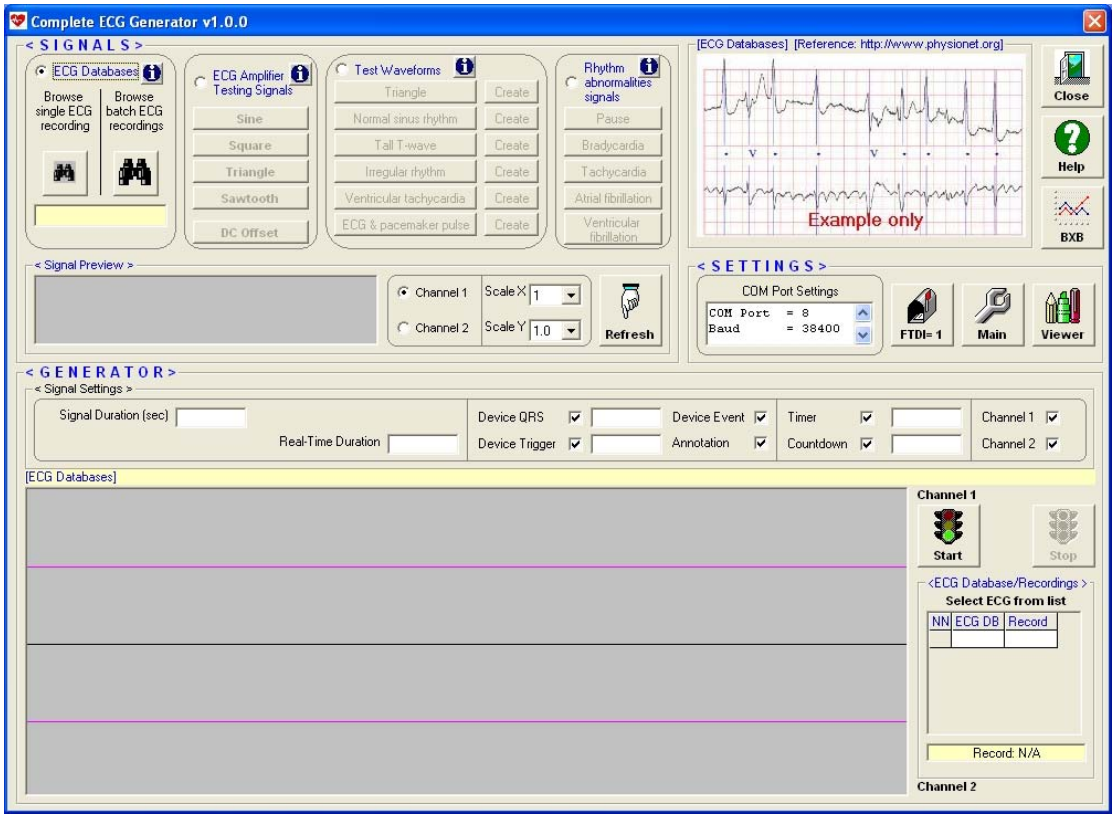
To change color for graph color settings selected from *Parameters* section click **Colors** button.

From Color interface select required color and click **OK** button.

To save Color setting changes click **Save** button.

4.2. Signal generation section

System supports 4 categories of generated signals.



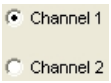
4.2.1. Signal Preview

This window allows for the display of the beginning of any selected signal.

It includes graph window, channel selection, scales selection and refresh preview window button.

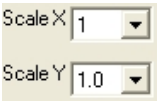
Channel 1 or 2 can be selected for two channel signal.

For the single channel signal (some of ECG Database and other signals) does not matter which channel was selected and will show the same signal graph in any selected channel.

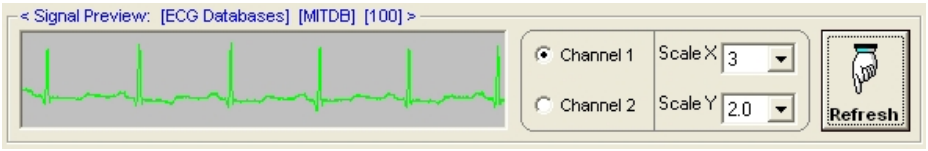


Signal graph can be resized in graph window in both horizontal and vertical direction from scale drop down boxes.

Scale option works only for Signal Preview window and does not change the original signal parameters during generation of the signal.



To see signal channel & scale changes click **Refresh** button.



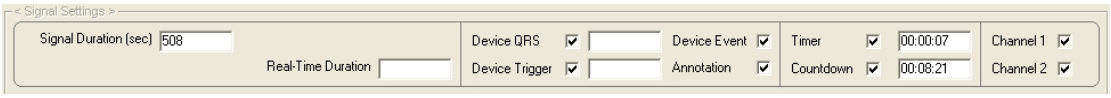
4.2.2. ECG Databases

ECG databases include digitized ECG signals and beat annotations. See **ECG Databases** reference from **Appendix A** and **Supported ECG Database Recordings** list from **Appendix B.**

4.2.2.1 ECG Database settings

In the database settings section several options can be selected by the user:

- ***Device QRS*** option, if enabled, will display QRS markers as vertical lines that drawn at the position of the QRS pulse received from the device under the test (see section 3 above).
- ***Device Trigger*** option, if enabled, will display Trigger markers as letter “T” at the position of the Trigger pulse received from the device under the test (see section 3 above).
- ***Device Event*** option, if enabled, will display Events by changing color of the ECG graphs at the beginning and the end of the Event.
- ***Annotation*** option, if enabled, will display annotation markers of the selected database recording.
- ***Timer*** option, if enabled, will display time elapsed since the beginning of the recording.
- ***Countdown*** option, if enabled, will display time to the end of the recording.
- ***Channel 1*** option, if enabled, will display ECG graph of Channel 1 of the database recording.
- ***Channel 2*** option, if enabled, will display ECG graph of Channel 2 of the database recording.



4.2.2.2 ECG Database signals

The system supports two options for generating database ECG signals:

- **Single** file,
- **Batch** option sequentially generates signals from all files in the selected database folder.
-

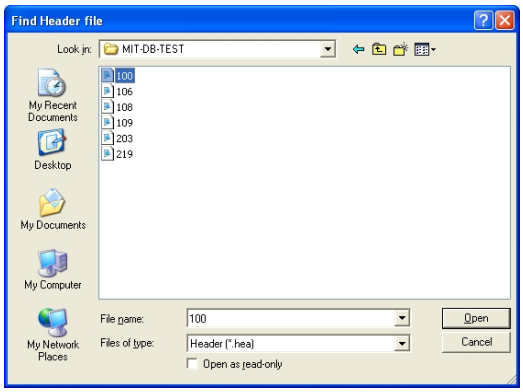
NOTE: Both Single and Batch options support bxb comparison of annotation files.

To open interface click **ECG Databases** option box.

To search for a **single ECG recording** click the button below.

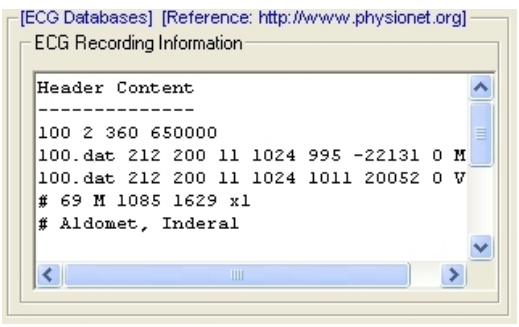
MIT-BIH Database example

Navigate to the MIT database folder and select a header file of the required recording.

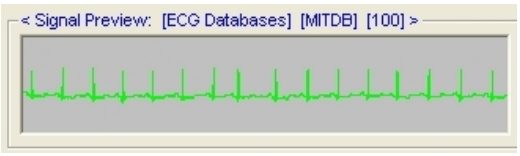


Information related to the selected recording:

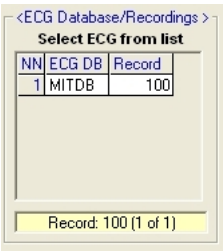
a. Header file content


[ECG Databases] [Reference: http://www.physionet.org]
ECG Recording Information
Header Content
100 2 360 650000
100.dat 212 200 11 1024 995 -22131 0 M
100.dat 212 200 11 1024 1011 20052 0 V
69 M 1085 1629 x1
Aldomet, Inderal

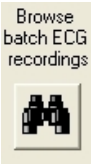
b. ECG file preview



c. List of recordings



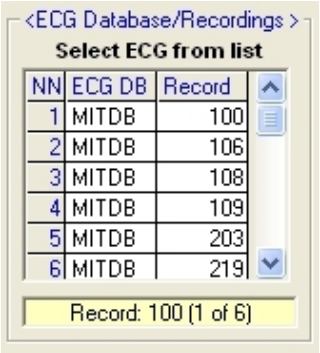
To search for a **batch of ECG recordings** click the button below.



From folder search interface select required ECG database folder with recording files.

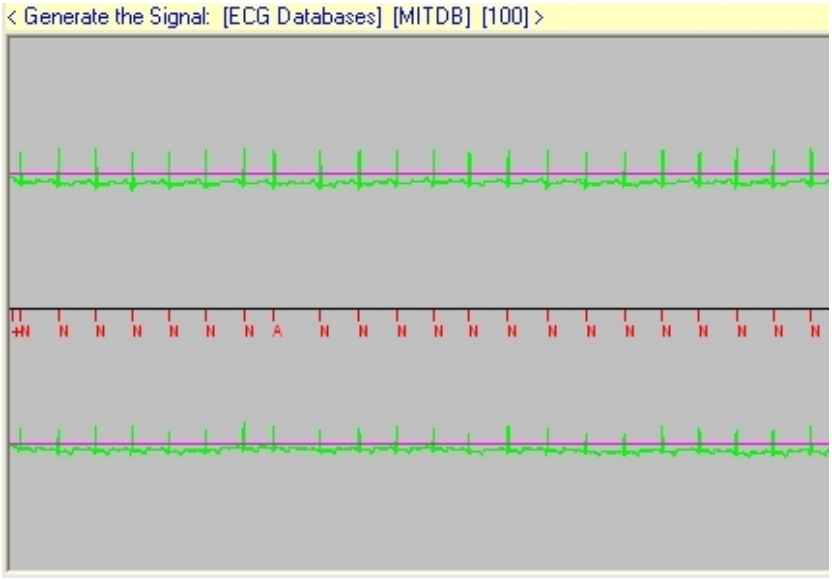
List of recordings includes all found supported recordings in the selected folder.

To see information related to any recording click on the corresponding recording number in the table below and it will show *Header file content* and *ECG file preview* as above.



To run signal generation process for ***single*** or ***batch*** recordings click **Start** button**.**

ECG window will show the generated signal and reference annotation marks.



After generation process is complete, test annotation file for each recording will be created in the test annotation folder (see **Appendix C - Files & Folders conventions**).

To terminate generation process click **Stop** button.

N.B. No annotation file will be created for terminated database playback.

4.2.3. ECG Amplifier testing signals

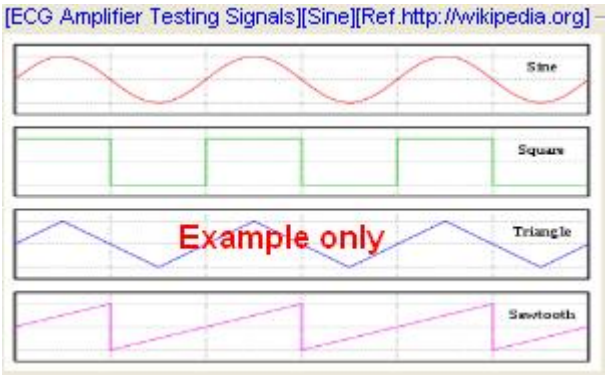
Common periodic waveforms include:

- **Sine wave**
  The amplitude of the waveform follows a trigonometric sine function with respect to time.

- **Square wave**
  This waveform is commonly used to assess filter function of the ECG amplifier.

- **Triangle wave**
  It contains odd harmonics.

- **Sawtooth wave**
  This looks like the teeth of a saw. Sawtooth wave of constant period contains odd and even harmonics.



DC Offset test signal

This signal is used to test DC offset performance of front end of ECG amplifier.
User selectable values of 0mV, ±100mV, ±200mV and ±300mV are available.
Square pulses ±2mV 1Hz are superimposed over selected DC offset.

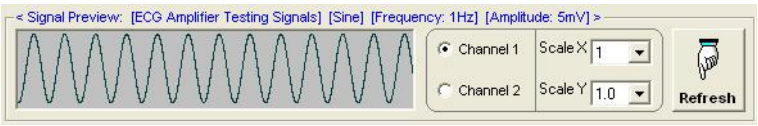
(See **ECG Amplifier testing signals** reference from **Appendix A).**

To open interface click **ECG Amplifier testing signals** option box.

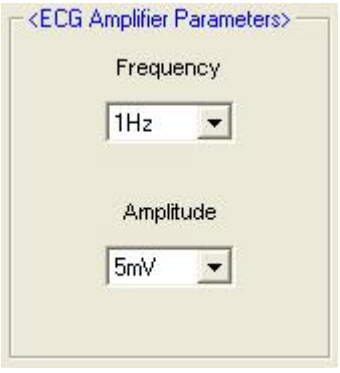
To select required waveform click **Sine**, **Square**, **Triangle, Sawtooth** or **DC Offset** button.

Sine waveform example

Sine signal preview window:

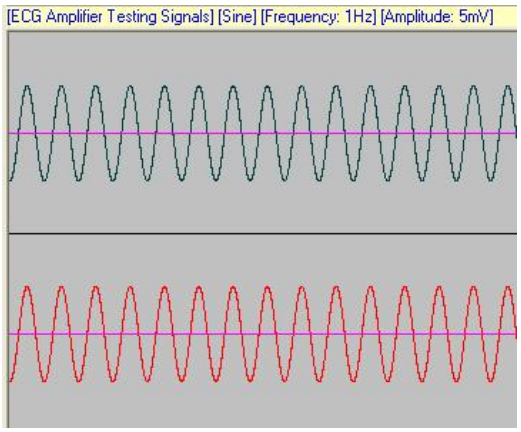


Frequency and **Amplitude** of the selected signal can be adjusted from **ECG Amplifier Parameters interface**:



To run signal generation process click **Start** button

Generated waveform graphs will be available for visual control in the **Generate the Signal** window:



To stop generation process click **Stop** button

Generation and visualization process for other **ECG Amplifier testing signals** are the same as for Sine waveform.

No annotation file will be generated for **ECG Amplifier testing signals.**

4.2.4. Test Waveforms

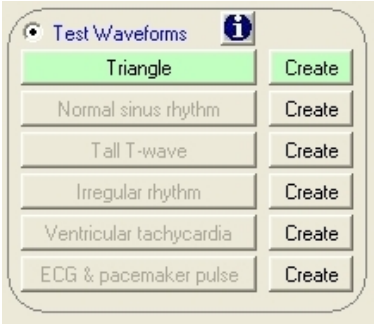
Test Waveforms signals are generated in accordance with ANSI/AAMI EC13:2002 (Cardiac monitors, heart rate meters, and alarms) standard.

The files in this set can be used for testing a variety of devices that monitor the electrocardiogram. The recordings include both synthetic and real waveforms.

See **Test Waveforms** reference in **Appendix A.**

To open interface click **Test Waveforms** option box.

To select required waveform click the appropriate button below:

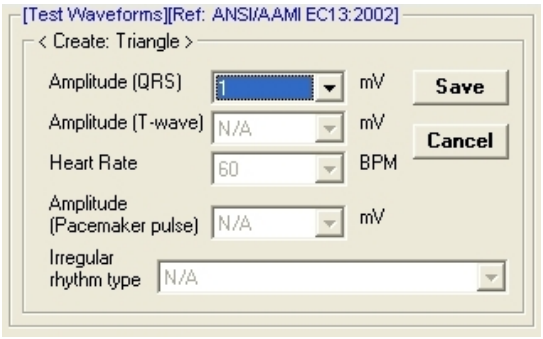


After installation of Application no test waveform information exists in the system.

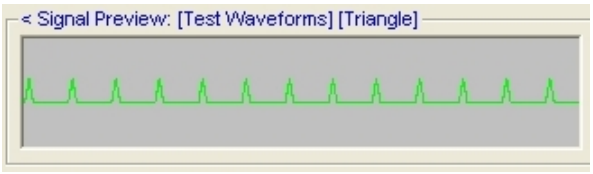
To make each of this signal available for generation click **Create** button on the right side of the required waveform button. It is user's responsibility to comply with AAMI copyright requirements when creating such waveforms.

Triangle waveform example

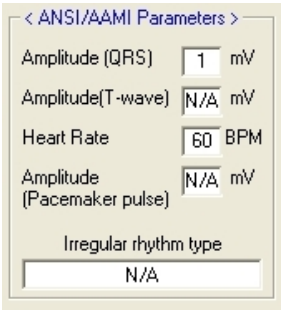
From the interface below select signal parameters from available drop down boxes and click **Save** button.



Triangle signal *preview* window

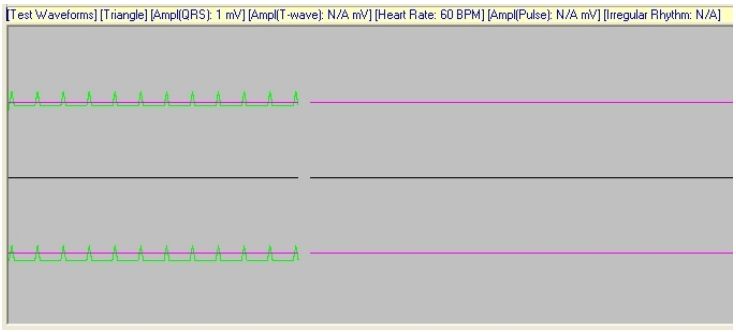


Triangle signal *parameters* window



To run signal generation click **Start** button

Generated waveform graphs are displayed in the **Generate the Signal** window.



To stop generation process click **Stop** button.

Generation and visualization process for other test waveforms is the same as for the Triangle waveform.

No annotation file will be generated for **Test Waveforms.**

4.2.5. Rhythm abnormalities signals

These signals help in development of QRS detectors and auto trigger function.
The user can select what kind of rhythm abnormality will be inserted into the normal sinus rhythm of 60bpm.
Duration of the normal sinus rhythm run is selected by the user.
Signal parameters are user selectable.

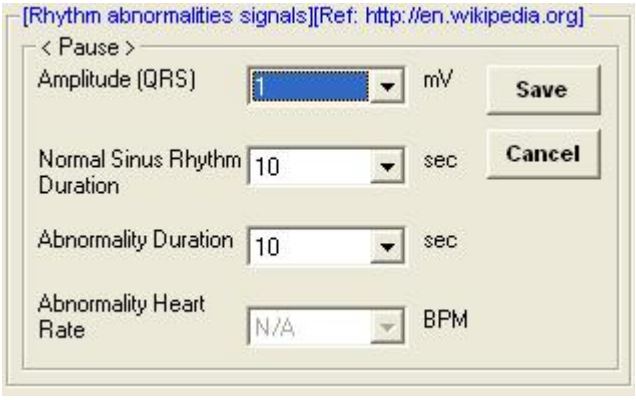
List of abnormalities include:

Pause.....	duration is set by the user
Bradycardia.....	40bpm (duration of the run is set by the user)
Tachycardia.....	140bpm (duration of the run is set by the user)
Atrial fibrillation.....	duration of the run is set by the user
Ventricular fibrillation……	duration of the run is set by the user

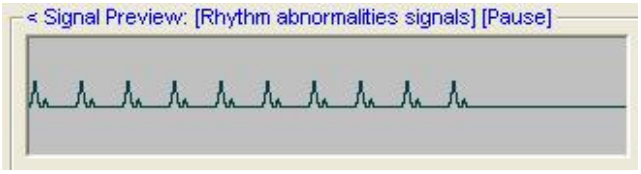
To **SELECT** required signal use ***Left mouse click*** the appropriate button below.
To **EDIT** required signal use ***Right mouse click*** the appropriate button below.

Pause signal example

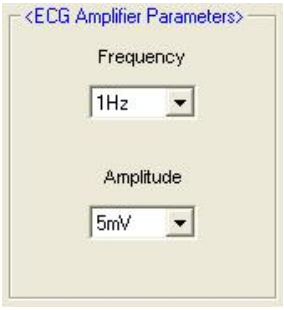
From the interface below select signal parameters from available drop down boxes and click **Save** button.



Pause signal *preview* window

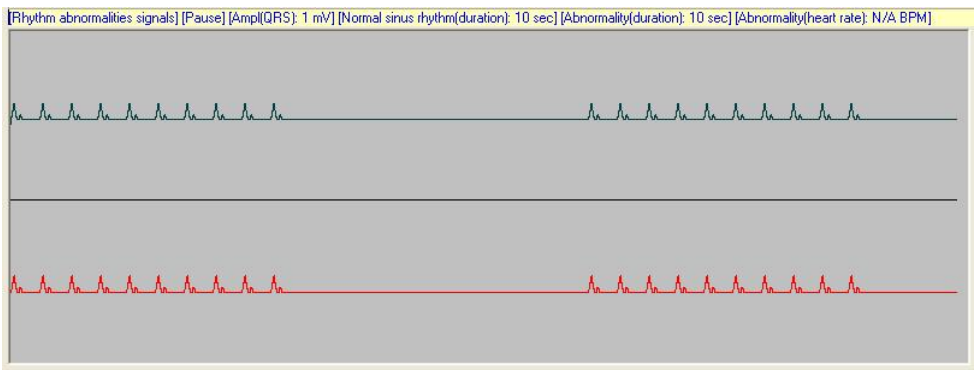


Pause signal *parameters* window



To run signal generation process click **Start** button

Generated signal graphs are displayed in the **Generate the Signal** window.


[Rhythm abnormalities signals] [Pause] [Ampl(QRS): 1 mV] [Normal sinus rhythm(duration): 10 sec] [Abnormality(duration): 10 sec] [Abnormality(heart rate): N/A BPM]

To stop generation process click **Stop** button:

Generation and visualization process for the other **Rhythm abnormalities signals** are the same as for the **Pause** signal.

No annotation file will be generated for **Rhythm abnormalities signals.**

4.3. bxb analysis section

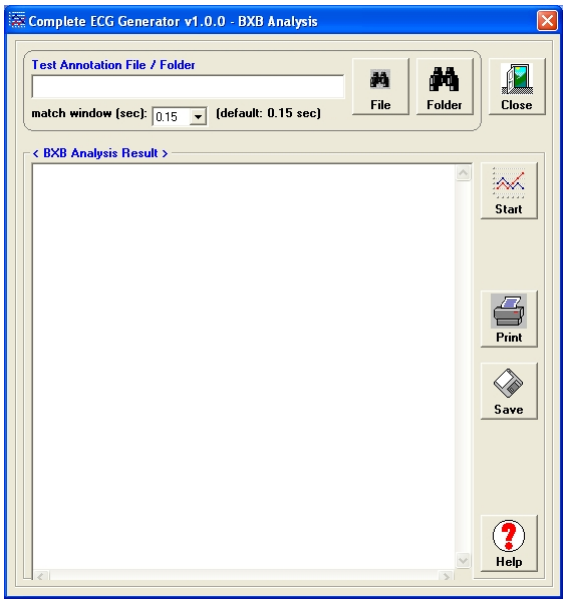
BXB Analysis uses beat-by-beat comparison algorithm described in ANSI/AAMI EC38:1998, the American National Standard for Ambulatory ECG monitors, and in ANSI/AAMI EC57:1998, the American National Standard for Testing and Reporting Performance Results of Cardiac Rhythm and ST Segment Measurement Algorithms.
(See **BXB Analysis** reference in **Appendix A.)**
bxb application is part of *WFDB Software Package*.
(See **WFDB Software Package** reference in **Appendix A.)**

To open *BXB Analysis* interface click **BXB** button:

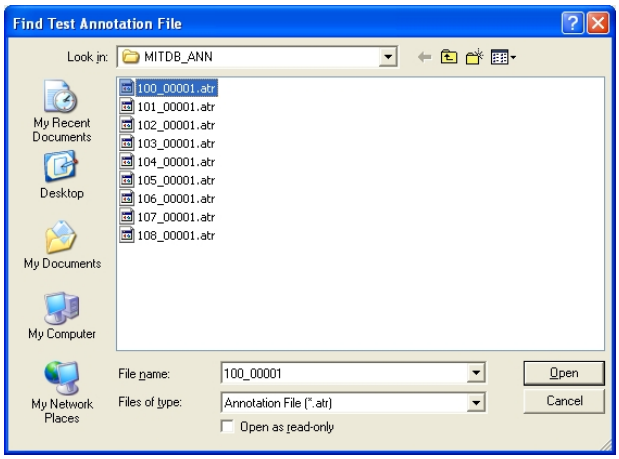
BXB Analysis interface includes 2 sections.

Test Annotation File / Folder section

- navigates to the single annotation file for bxb analysis
- navigates to the batch of annotation files for bxb analysis
- adjusts match window

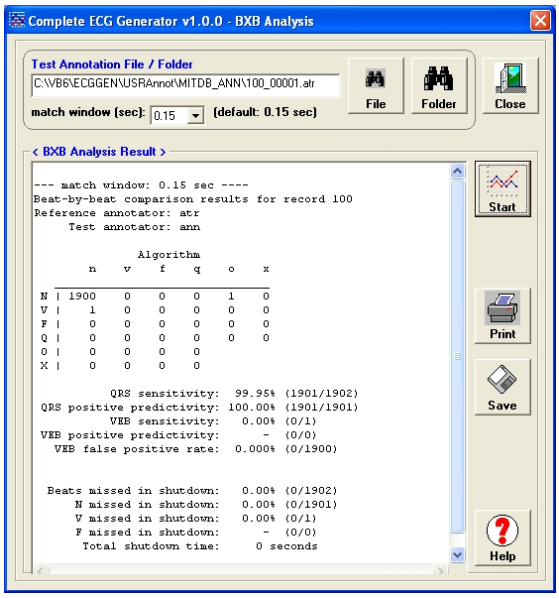


To navigate to the test annotation file click **File** button.

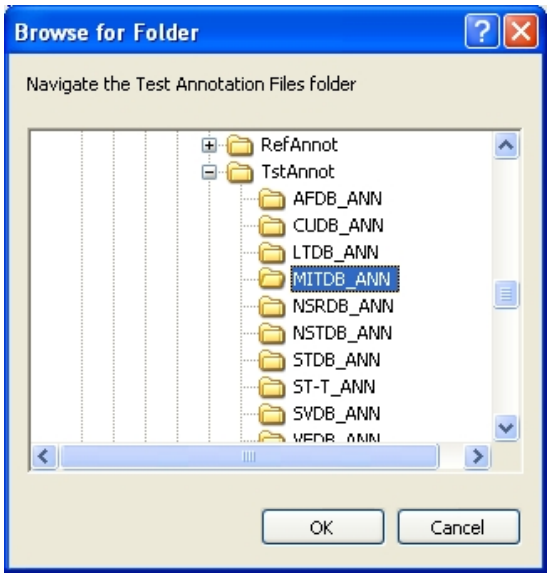


Select required test annotation ***file*** and click **Start** button.

Results will be shown in *BXB Analysis Result* window:

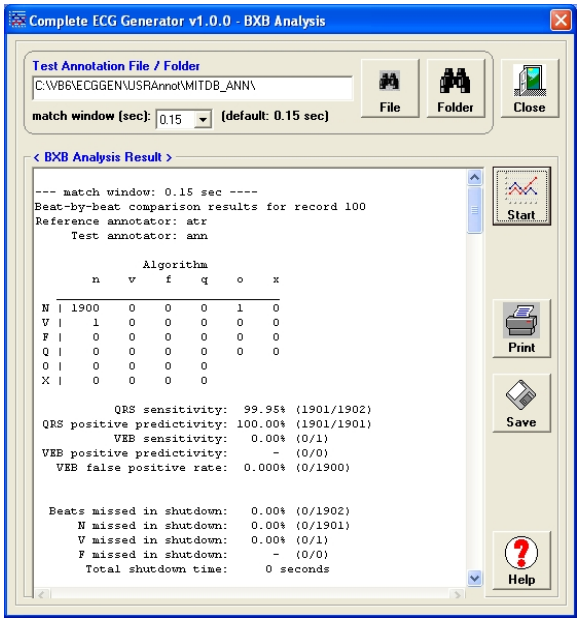

Complete ECG Generator v1.0.0 - BXB Analysis
Test Annotation File / Folder
C:\WB6\ECGGEN\USRAnnot\MITDB_ANN\100_00001.atr
match window (sec): 0.15 (default: 0.15 sec)
File
Folder
Close
< BXB Analysis Result >
--- match window: 0.15 sec ----
Beat-by-beat comparison results for record 100
Reference annotator: atr
Test annotator: ann
Algorithm
n v f q o x
N | 1900 0 0 0 1 0
V | 1 0 0 0 0 0
F | 0 0 0 0 0 0
Q | 0 0 0 0 0 0
O | 0 0 0 0
X | 0 0 0 0
QRS sensitivity: 99.95% (1901/1902)
QRS positive predictivity: 100.00% (1901/1901)
VEB sensitivity: 0.00% (0/1)
VEB positive predictivity: - (0/0)
VEB false positive rate: 0.000% (0/1900)
Beats missed in shutdown: 0.00% (0/1902)
N missed in shutdown: 0.00% (0/1901)
V missed in shutdown: 0.00% (0/1)
F missed in shutdown: - (0/0)
Total shutdown time: 0 seconds
Start
Print
Save
Help

To navigate to the batch of test annotation files click **Folder** button.



Click OK button when select required test annotation files ***folder,*** then click **Start** button.

Results will be shown in *BXB Analysis Result* window:


Complete ECG Generator v1.0.0 - BXB Analysis
Test Annotation File / Folder
C:\VB6\ECGGEN\USRAnnot\MITDB_ANN\
File
Folder
Close
match window (sec): 0.15
(default: 0.15 sec)
< BXB Analysis Result >
--- match window: 0.15 sec ----
Beat-by-beat comparison results for record 100
Reference annotator: atr
Test annotator: ann
Algorithm
n v f q o x
N | 1900 0 0 0 1 0
V | 1 0 0 0 0 0
F | 0 0 0 0 0 0
Q | 0 0 0 0 0 0
O | 0 0 0 0
X | 0 0 0 0
QRS sensitivity: 99.95% (1901/1902)
QRS positive predictivity: 100.00% (1901/1901)
VEB sensitivity: 0.00% (0/1)
VEB positive predictivity: - (0/0)
VEB false positive rate: 0.000% (0/1900)
Beats missed in shutdown: 0.00% (0/1902)
N missed in shutdown: 0.00% (0/1901)
V missed in shutdown: 0.00% (0/1)
F missed in shutdown: - (0/0)
Total shutdown time: 0 seconds
Start
Print
Save
Help

BXB Analysis for both annotation File and Folder can be created with adjustable (from drop down box) **match window**.

BXB Analysis Result section

- makes bxb analysis
- shows bxb analysis results in window
- prints bxb analysis results
- saves bxb analysis results in text file.

(See **Appendix C - Files & Folders conventions**).

Appendix A – Reference Links

ECG Databases:
http://www.physionet.org/physiobank/database/#ecg

ECG Amplifier testing signals:
http://en.wikipedia.org/wiki/Waveform
http://en.wikipedia.org/wiki/DC_bias

Test Waveforms:
http://www.physionet.org/physiobank/database/aami-ec13/

BXB Analysis:
http://www.physionet.org/physiotools/wag/bxb-1.htm

WFDB Software Package:
http://www.physionet.org/physiotools/wfdb.shtml

FTDI driver:
http://www.ftdichip.com/FTDrivers.htm

Adobe Acrobat Reader:
http://get.adobe.com/reader/

Appendix B - Supported ECG Database & Recordings

AFDB: MIT-BIH Atrial Fibrillation Database

This database includes 25 long-term ECG recordings of human subjects with atrial fibrillation (mostly paroxysmal).

supported 23 ECG recordings

04015	**04936**	**06995**	**08219**
04043	**05091**	**07162**	**08378**
04048	**05121**	**07859**	**08405**
04126	**05261**	**07879**	**08434**
04746	**06426**	**07910**	**08455**
04908	**06453**	**08215**	

CUDB: Creighton University Ventricular Tachyarrhythmia Database

This database includes 35 eight-minute ECG recordings of human subjects who experienced episodes of sustained ventricular tachycardia, ventricular flutter, and ventricular fibrillation.

supported 34 ECG recordings

cu01	**cu08**	**cu15**	**cu22**	**cu30**
cu02	**cu09**	**cu16**	**cu23**	**cu31**
cu03	**cu10**	**cu17**	**cu24**	**cu32**
cu04	**cu11**	**cu18**	**cu25**	**cu33**
cu05	**cu12**	**cu19**	**cu26**	**cu34**
cu06	**cu13**	**cu20**	**cu28**	**cu35**
cu07	**cu14**	**cu21**	**cu29**	

LTDB: Long-Term ST Database

This database contains 7 long-term ECG recordings (14 to 22 hours each), with manually reviewed beat annotations.

supported 6 ECG recordings

14046	**14134**	**14149**	**14157**	**14172**	**14184**

MITDB: MIT-BIH Arrhythmia Database

The MIT-BIH Arrhythmia Database contains 48 half-hour excerpts of two-channel ambulatory ECG recordings, obtained from 47 subjects studied by the BIH Arrhythmia Laboratory between 1975 and 1979.

supported 48 ECG recordings

100	**108**	**117**	**201**	**212**	**222**
101	**109**	**118**	**202**	**213**	**223**
102	**111**	**119**	**203**	**214**	**228**
103	**112**	**121**	**205**	**215**	**230**
104	**113**	**122**	**207**	**217**	**231**
105	**114**	**123**	**208**	**219**	**232**
106	**115**	**124**	**209**	**220**	**233**
107	**116**	**200**	**210**	**221**	**234**

NSRDB: MIT-BIH Normal Sinus Rhythm Database

This database includes 18 long-term ECG recordings of subjects referred to the Arrhythmia Laboratory at Boston's Beth Israel Hospital (now the Beth Israel Deaconess Medical Center).

supported 18 ECG recordings

16265	**16773**	**18184**
16272	**16786**	**19088**
16273	**16795**	**19090**
16420	**17052**	**19093**
16483	**17453**	**19140**
16539	**18177**	**19830**

NSTDB: MIT-BIH Noise Stress Test Database

The ECG recordings were created using two clean recordings (118 and 119) from the MIT-BIH Arrhythmia Database, to which calibrated amounts of noise were added.

supported 8 ECG recordings

118E06	**119E06**
118E12	**119E12**
118E18	**119E18**
118E24	**119E24**

STDB: MIT-BIH ST Change Database

This database includes 28 ECG recordings of varying lengths, most of which were recorded during exercise stress tests and which exhibit transient ST depression.

supported 28 ECG recordings

300	**307**	**314**	**321**
301	**308**	**315**	**322**
302	**309**	**316**	**323**
303	**310**	**317**	**324**
304	**311**	**318**	**325**
305	**312**	**319**	**326**
306	**313**	**320**	**327**

ST-T : European ST-T Database

This database includes 90 ECG recordings and is intended to be used for evaluation of algorithms for analysis of ST and T-wave changes.

supported 84 ECG recordings

e0103	**e0118**	**e0139**	**e0203**	**e0304**	**e0413**	**e0605**	**e0801**
e0104	**e0119**	**e0148**	**e0204**	**e0305**	**e0415**	**e0606**	**e0808**
e0105	**e0121**	**e0151**	**e0205**	**e0306**	**e0417**	**e0607**	**e0817**
e0106	**e0122**	**e0154**	**e0207**	**e0403**	**e0418**	**e0609**	**e0818**
e0108	**e0123**	**e0155**	**e0208**	**e0404**	**e0501**	**e0610**	**e1301**
e0110	**e0124**	**e0159**	**e0210**	**e0405**	**e0509**	**e0611**	**e1302**
e0111	**e0125**	**e0161**	**e0211**	**e0406**	**e0515**	**e0612**	**e1304**
e0112	**e0126**	**e0162**	**e0212**	**e0408**	**e0601**	**e0613**	
e0113	**e0127**	**e0163**	**e0213**	**e0409**	**e0602**	**e0614**	
e0115	**e0133**	**e0170**	**e0302**	**e0410**	**e0603**	**e0615**	
e0116	**e0136**	**e0202**	**e0303**	**e0411**	**e0604**	**e0704**	

SVDB: MIT-BIH Supraventricular Arrhythmia Database

This database includes 78 half-hour ECG recordings chosen to supplement the examples of supraventricular arrhythmias in the MIT-BIH Arrhythmia Database.

supported 75 ECG recordings

800	**810**	**827**	**847**	**859**	**870**	**880**	**890**
801	**811**	**828**	**848**	**860**	**871**	**881**	**891**
802	**812**	**829**	**849**	**861**	**872**	**882**	**892**
803	**820**	**840**	**850**	**863**	**873**	**883**	**893**
804	**821**	**841**	**852**	**864**	**874**	**884**	**894**
805	**822**	**842**	**853**	**865**	**875**	**885**	
806	**823**	**843**	**855**	**866**	**876**	**886**	
807	**824**	**844**	**856**	**867**	**877**	**887**	
808	**825**	**845**	**857**	**868**	**878**	**888**	
809	**826**	**846**	**858**	**869**	**879**	**889**	

VFDB: MIT-BIH Malignant Ventricular Arrhythmia Database

This database includes 22 half-hour ECG recordings of subjects who experienced episodes of sustained ventricular tachycardia, ventricular flutter, and ventricular fibrillation.

supported 22 ECG recordings

418	**424**	**430**	**611**
419	**425**	**602**	**612**
420	**426**	**605**	**614**
421	**427**	**607**	**615**
422	**428**	**609**	
423	**429**	**610**	

AHA : Database for Evaluation of Ventricular Arrhythmia Detectors

Two versions of the database are available: the **short version** includes five minutes of unannotated ECG signals prior to the thirty-minute annotated segment of each recording, and the **long version** includes 2.5 hours of unannotated ECG signals prior to each annotated segment.

supported 154 ECG recordings (long version)

1001	**2001**	**3001**	**4001**	**5001**	**6001**	**7001**	**8001**
1002	**2002**	**3002**	**4002**	**5002**	**6002**	**7002**	**8002**
1003	**2003**	**3003**	**4003**	**5003**	**6003**	**7003**	**8003**
1004	**2004**	**3004**	**4004**	**5004**	**6004**	**7004**	**8004**
	2005	**3005**	**4005**	**5005**	**6005**	**7005**	**8005**
1006	**2006**	**3006**	**4006**	**5006**	**6006**	**7006**	**8006**
1007	**2007**	**3007**	**4007**	**5007**	**6007**	**7007**	**8007**
1008	**2008**	**3008**	**4008**	**5008**	**6008**	**7008**	**8008**
1009	**2009**	**3009**	**4009**	**5009**	**6009**	**7009**	**8009**
1010	**2010**	**3010**	**4010**	**5010**	**6010**	**7010**	**8010**
1101	**2101**	**3101**	**4101**	**5101**	**6101**	**7101**	**8101**
1102	**2102**	**3102**	**4102**	**5102**	**6102**	**7102**	**8102**
1103	**2103**	**3103**	**4103**	**5103**	**6103**	**7103**	**8103**
1104	**2104**	**3104**	**4104**	**5104**	**6104**	**7104**	**8104**
1105	**2105**	**3105**	**4105**	**5105**	**6105**	**7105**	**8105**
1106	**2106**	**3106**	**4106**		**6106**	**7106**	**8106**
1107	**2107**	**3107**	**4107**		**6107**	**7107**	**8107**
1108	**2108**	**3108**	**4108**		**6108**	**7108**	**8108**
1109	**2109**	**3109**	**4109**		**6109**	**7109**	**8109**
1110	**2110**	**3110**	**4110**		**6110**	**7110**	**8110**

supported 154 ECG recordings (short version)

1201	**2201**	**3201**	**4201**	**5201**	**6201**	**7201**	**8201**
1202	**2202**	**3202**	**4202**	**5202**	**6202**	**7202**	**8202**
1203	**2203**	**3203**	**4203**	**5203**	**6203**	**7203**	**8203**
1204	**2204**	**3204**	**4204**	**5204**	**6204**	**7204**	**8204**
	2205	**3205**	**4205**	**5205**	**6205**	**7205**	**8205**
1206	**2206**	**3206**	**4206**	**5206**	**6206**	**7206**	**8206**
1207	**2207**	**3207**	**4207**	**5207**	**6207**	**7207**	**8207**
1208	**2208**	**3208**	**4208**	**5208**	**6208**	**7208**	**8208**
1209	**2209**	**3209**	**4209**	**5209**	**6209**	**7209**	**8209**
1210	**2210**	**3210**	**4210**	**5210**	**6210**	**7210**	**8210**
1301	**2301**	**3301**	**4301**	**5301**	**6301**	**7301**	**8301**
1302	**2302**	**3302**	**4302**	**5302**	**6302**	**7302**	**8302**
1303	**2303**	**3303**	**4303**	**5303**	**6303**	**7303**	**8303**
1304	**2304**	**3304**	**4304**	**5304**	**6304**	**7304**	**8304**
1305	**2305**	**3305**	**4305**	**5305**	**6305**	**7305**	**8305**
1306	**2306**	**3306**	**4306**		**6306**	**7306**	**8306**
1307	**2307**	**3307**	**4307**		**6307**	**7307**	**8307**
1308	**2308**	**3308**	**4308**		**6308**	**7308**	**8308**
1309	**2309**	**3309**	**4309**		**6309**	**7309**	**8309**
1310	**2310**	**3310**	**4310**		**6310**	**7310**	**8310**

supported 1 ECG recording sample (short version)

0201 - record that was excluded from the AHA Database is available for download from physionet.org

N.B. CEG does NOT support AHA database files in native AHA format.
To use CEG for AHA files, it's compulsory to convert AHA files (.txt, .ecg etc.) to MIT-BIH 2012 format by converters from physionet.org:

http://www.physionet.org/physiotools/wag/a2m-1.htm

Appendix C - Files & Folders conventions

- \application folder – folder where application was installed

- \application folder**ecggen.exe** – application executable file

- \application folder**ecggen.mdb** – system database file

- \application folder**user_manual.pdf** – this is the User Manual file

- \application folder**RefAnnot** – folder which includes folders with supported ECG database names as: **\AFDB**, **\CUDB**, **\LTDB**, **\MITDB**, **\NSRDB**, **\NSTDB**, **\STDB**, **ST-T, \SVDB**, **\VFDB**.

  Each of these folders include supported ***reference*** **annotation** and **header** files and at least one supported **ECG** recording file

- \application folder**TstAnnot** – folder which includes folders with supported ECG database names as: **\AFDB_ANN**, **\CUDB_ANN**, **\LTDB_ANN**, **\MITDB_ANN**, **\NSRDB_ANN**, **\NSTDB_ANN**, **\STDB_ANN**, **\ST-T_ANN, \SVDB_ANN**, **\VFDB_ANN**.

  Each of these folders include ***test*** **annotation files** for each tested recording and **bxb analysis result files** both for single and batch analysis

- \application folder**WFDB** – folder which includes **WFDB Software Package** (library & applications)

Warning

Manual changing the any of Complete ECG Generator System file/folder can terminate proper system functionality.

Appendix D - Troubleshooting

1 - Device is not recognized by Application

Solution:

- Check FTDI driver was installed

- Disconnect all FTDI devices from PC

- Check if Complete ECG Generator Device is connected to PC

- Check from Complete ECG Generator Application (Main Settings) and MS Windows Device Manager utility the correct COM port

- If Device does not respond due to unexpected errors, it is recommended to disconnect USB cable for 15 seconds and connect it again.

2 – Error messages related to files, folders and system database

Solution:

- Make backup of Test Annotation folder **TstAnnot** and reinstall Complete ECG Generator Application

- Restore Test Annotation folder **TstAnnot** to Application folder

Warning

Operation of the System under MS Windows environment is extremely timing sensitive. Therefore, it is recommended to use a computer that has no residential programs (antivirus / antispyware and alike) running and no new applications shall be launched during operation of the Complete ECG Generator System.

Appendix E – Signal quality and working setup

Due to highly sensitive ECG amplifier under test and common mode noise emitted by the working hardware around working site, it is important to maintain low noise environment when using Complete ECG Generator.

Below some examples of the amplifier output noise in different working setups. All three samples are made using MITDB recording 100.

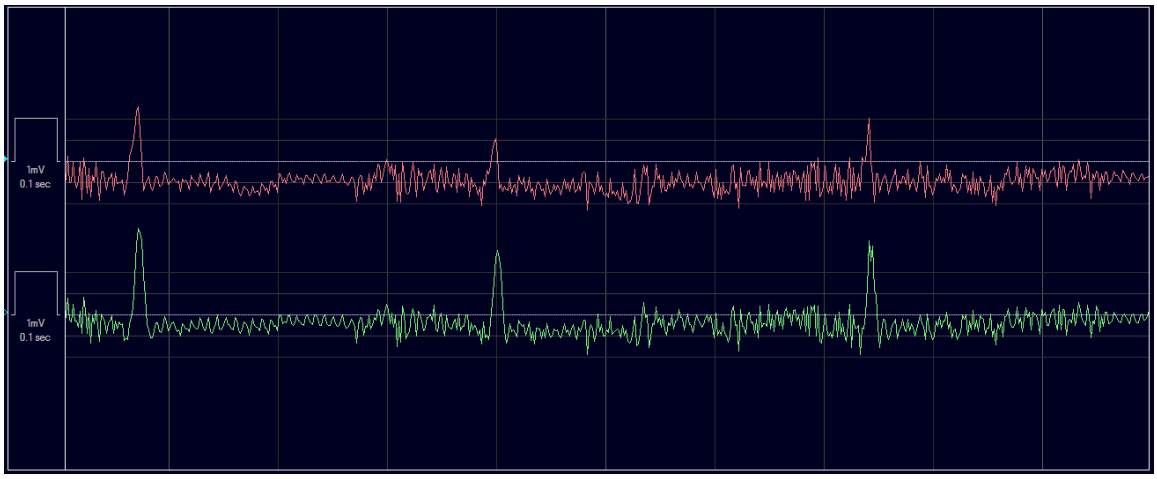


FIG E.1 Very noisy environment. Three desktop computers, oscilloscope and signal generator operating and big antistatic mat in close proximity. CEG is connected to and powered by one of the desktop PCs.

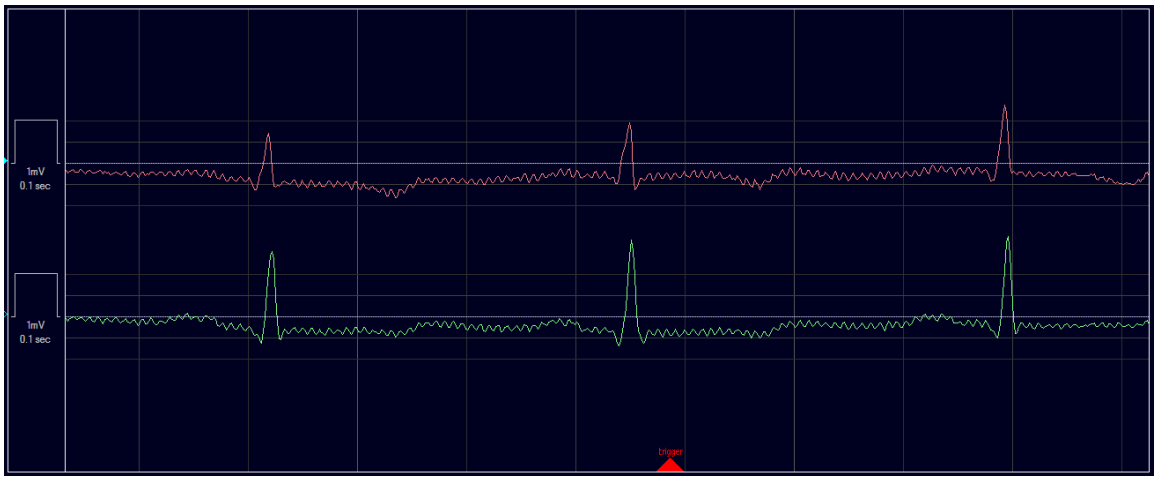


FIG E.2 Good environment. No power hungry hardware operating in close proximity. CEG is connected to and powered by laptop computer with mains power supply

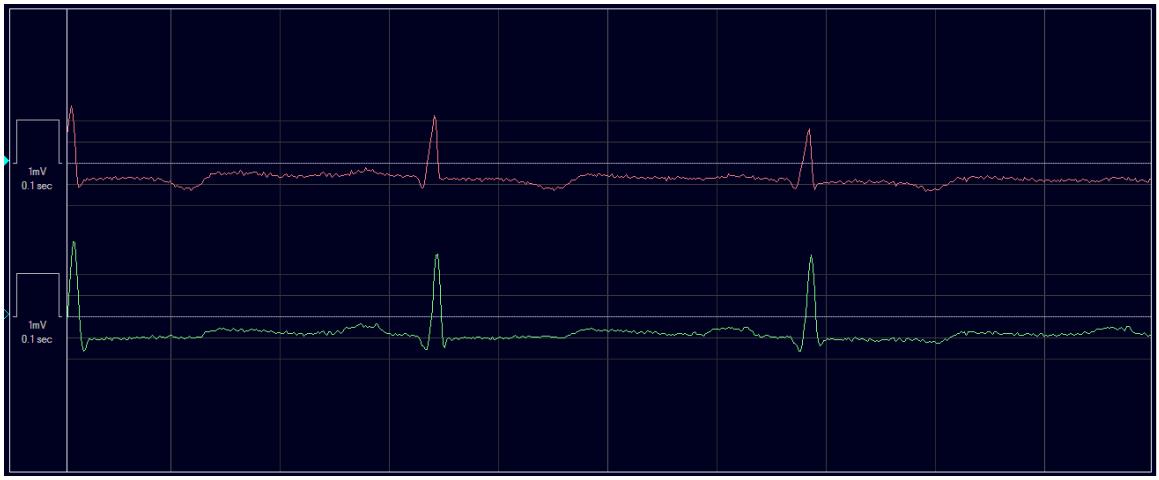


FIG E.3 Good environment. No power hungry hardware operating in close proximity. CEG is connected to and powered by battery operated laptop computer